Research Article

Butterfly Diversity from Farmlands of Central Uganda

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The aim of this study was to collect information about the diversity of butterfly communities in the mixed coffee-banana mosaic (seminatural, agricultural) landscapes of rural central Uganda. Data were collected for one year (2006) using fruit-bait traps, line transect walk-and-counts, and hand nets. A total of 56,315 individuals belonging to 331 species, 95 genera, and 6 families were sampled. The most abundant species was *Bicyclus safitza* (14.5%) followed by *Acraea acerata* (6.3%), *Catopsilia florella* (6.5%) and *Junonia sophia* (6.1%). Significant differences in abundance, species richness, and diversity of butterflies occurred between the 26 study sites. Farmland butterflies visited a variety of habitats within and around sites, but important habitats included woodlands, fallows, hedgerows, swampy habitats, abandoned gardens, and home gardens. The highest diversity and abundance of butterflies occurred in sites that contained forest remnants. Thus, forest reserves in the surrounding of fields increased the conservation values of coffee-banana agroforestry systems for butterflies. Their protection from degradation should be a priority for policy makers since they support a species-rich community of butterflies pollinating cultivated plants. Farmers are encouraged to protect and increase on-farm areas covered by complex traditional agroforests, linear, and nonlinear seminatural habitats to provide sufficient breeding sites and nectar resources for butterflies.

1. Introduction

Butterflies are considered as good ecological indicators for other invertebrate taxa [1–3] and as surrogate representatives of environmental quality changes. Butterflies play significant ecological roles in agricultural landscapes. They perform essential ecosystem services [4], especially in the recycling of nutrients (N, P, K) highly needed by crops that were previously taken through plant absorption and uptake. Their larval stages feed on leaves of several wild plants found in the agricultural systems and therefore release their faeces that contain some amount of nutrients [5]. In addition, butterflies are food to birds and other predators and are hosts to several parasitoids that suppress crop pests [6].

Despite their diversity, ubiquity, and importance particularly with regard to their ecology, behavior, and functional

role (e.g., pollination activities), butterflies remain relatively little studied in farmland habitats [5] in the tropics. In agricultural systems, several butterfly species are suspected to be important pollinators of wild and cultivated crop species on which human beings depend on for their livelihoods [7].

Among the invertebrates, butterflies are one of the best studied insect groups for which both ecological and relatively good quantitative distribution data are available worldwide. In Mediterranean countries [8], knowledge of butterflies inhabiting farmland habitats is fairly good compared to most of the regions of sub-Saharan Africa where the knowledge is poor or absent.

Roughly 90% of butterfly species live in the tropics [7]. Despite this, very little is known about tropical farmland butterfly ecology particularly when compared to temperate butterfly systems. The relative scarcity of data on

tropical butterfly species hampers the ability to effectively conserve them, particularly as pollinating agents in agricultural systems.

In Uganda, most studies on butterflies have been carried out in natural areas, forest ecosystems, and in protected areas [9–12]. There is a lack of empirical data on butterflies from farmland habitats in sub-Saharan Africa and in Uganda. No published data exists describing the diversity of butterflies found in agricultural landscapes in Uganda. However, such information is important for butterfly biodiversity and ecosystem services conservation on farmlands.

Because butterflies provide important ecological services for crops and native wild plant species in many ecosystems of the world [13], their conservation is essential to sustain the productivity of natural and agricultural landscapes. However, the protection, conservation, and utilization of Lepidoptera pollinator diversity require extensive understanding of their foraging behaviours and of their temporal and spatial distribution in agricultural landscapes [14, 15]. Farmland habitats support a rich and functionally diverse butterfly community.

Preliminary field observations conducted in central Uganda [7] indicated that some butterfly species are present and busy collecting floral resources in vegetable and legume crop fields later in the morning hours to evening time. Although a proper assessment of pollination efficiency of different species has not been conducted, the abundance and long visits to crop flowers indicated that some of these crops were receiving butterfly pollination services [7]. Preliminary observations indicated also that the annual contribution of butterflies to total pollination services delivered to crops in Uganda is in the range from 4.0% to 9.0% [7]. Thus, butterflies may constitute the second group of crop pollinators behind bees in central Uganda [7]. It is likely that some species are both good pollinators of some cultivated and wild plant species. There is a need to conserve butterflies in rural landscapes of central Uganda.

The aim of this study was to collect information on the current status of butterflies in farmlands of central Uganda. The specific objectives were (i) to characterize butterfly assemblages (abundance, species richness and diversity) on farmlands of central Uganda, (ii) to compare butterfly assemblages in sites with different seminatural habitats/land-uses and farm management systems, and to identify environmental factors (land-uses, habitats) mostly determining the distribution and occurrence of different species in the farmlands of central Uganda.

In this study, it was hypothesized that farmlands do not support diverse butterfly communities. It is predicted that butterfly assemblages on farmlands in sites with different land-uses, seminatural habitats and farm management systems in central Uganda are of similar taxa given the farmland character that is over-cultivated.

2. Material and Methods

2.1. Study Area. This study was conducted in the banana-coffee system of Lake Victoria Arc covering several districts

of the central Uganda (Figure 1). The study zone is characterized by ferrisols with high to medium fertility level and receives on average 1000–1800 mm of rains on a bimodal pattern (rainy seasons: March–May, September–November; semi-dry to dry seasons: June–August, December–February) with 22–28°C and 60–75% of mean annual temperature and relative humidity respectively [7]. The study zone is farmland area found around Lake Victoria. The farmland zone is characterized with shrubs of *Acacia* spp., legume trees, melliferous plant species, *Papyrus* and palms ranging from 2 to 15 m high dominating the remnant secondary vegetation.

Several food and cash crops are grown, mainly cassava (*Manihot esculentum* L.), sweet potato, (*Ipomoea batatas* L.), maize (*Zea mays*), beans (*Phaseolus vulgaris* L.), groundnut (*Arachis hypogea* L.), tomato (*Lycopersicon esculentum*), watermelon (*Citrullus lanatus*), pumpkin (*Cucurbita moschata*), cucumber (*Cucumis sativus*), melon (*Cucumis melo*), chilies (*Capsicum* spp.), and several other fruits, vegetables and horticultural crops (cabbage, onion, egg plants, sim-sim, etc.). The majority of these crops are grown in small-scale monoculture and/or polyculture fields that are integrated into the coffee-banana agroforest production systems where coffee and banana are the major crops.

Rural central Uganda is mosaic landscape where “islands” of patches of natural habitats (forest reserves, wetlands, woodlands) are found scattered within agricultural matrices dominated by linear and nonlinear features of seminatural habitats (fallow, hedgerows, grasslands, woodlots, rangelands) that serve as field boundaries for a diversity of small-scale fields. Compared to other regions of Uganda, central region is characterized by high demographic pressure, limited access to arable lands, continuous cultivation, and overexploited lands.

This study was conducted at 26 study sites that were previously selected to represent a range of land-use types of varying degrees of anthropogenic disturbances and farm management intensities. Thus, all study sites were characterized by the presence of contrasting habitat and land-use types in the vicinity. The different study sites were grouped into clusters such as each cluster contained 2 to 4 study sites. The different study sites were separated from one another by a distance from 5 to 50 km. The different study sites were later regrouped into different farm management systems (modernized large-scale fields, traditional small-scaled fields). They were also grouped into clusters of different land-use intensity gradients or categories (low, medium, high, very high). Detailed description of the different land-use intensity classes occurring in the study area are presented in Munyuli [7]. Characteristics of dominant agroforestry systems found in central Uganda are presented in Table 1.

2.2. Field Sampling of Butterflies. Field sampling of butterflies was conducted at 26 study sites. In each of the 26 study sites, an area of 1 km² was selected and the area was divided into five linear parallel transects of 1000 m long and 200 m apart (Figure 2). Transects were used as basic sampling

TABLE 1: Type of common agroforestry systems found in farmlands of central Uganda.

Cluster names	Study site names	Type of traditional agroforestry systems	Size range (ha) of the agroforest	Other vegetation characteristics of the traditional agroforests	Closeness or distance to water bodies	Dominant natural habitats, seminatural habitats, and vegetation types found within, around, and in the vicinity of sites
Bujaggali	Bukose	Shaded coffee-banana agroforests	10–100	Mass blooming of weeds/herbs in the ground layer	30 m to wetlands	Reclaimed wetlands, young fallows, field margins, woodlands
	Namizi-east	Multistrata complex shaded banana-coffee agroforests	10–500	(i) Multipurpose agroforest tree species (ii) Forest remanent tree species	4000 m to swamps	Forest fallows, young fallows, grasslands, pastures, marshlands, swamps, wetlands
	Namizi-west	Simple banana-coffee agroforests	10–50	(i) Tin wild woody trees in the lower layer (ii) Some invasive tree species	5000 m to river Nile	Conifer plantations, pine/eucalyptus plantations, old fallows, grazing fields, large swamps, forest fallows
	Nawangoma	Simple agroforests, homegardens	10–100	(i) Diverse shade tree species (ii) Diverse fruit tree species (iii) Ruderal vegetation in bloom	7000 m to Lake Kyoga	Woodlands, shrublands with several deciduous trees, hedgerows, field margins, forest plantations, degraded/cleared forest patches
	Bamusuta	Complex shaded banana-coffee agroforests	10–50	(i) Mass blooming weeds/herbs in ground layer	1000 m to wetlands	Young fallows, hedgerows, forest fallows
Kalagi	Kifu	Complex banana-coffee agroforests	10–700	(i) Mass blooming of ruderal vegetation in the ground layer, (ii) Native tree species in the canopy	200 m to swamps	Wood-shrub grasslands, grasslands, cattle pastures, swampy forests, forest reserves
	Kimwanyi	Simple shaded coffee-banana agroforests	10–50	(i) Multistrata mass blooming weeds/herbs at the ground layer (ii) Coffee shrubs in the upper layer	500 m to streams	Eucalyptus plantations, wood-shrub grasslands, young fallows, hedgerows, cattle pastures, forest plantations, large wetlands
	Kiweebwa	Complex banana coffee-agroforests	10–900	(i) Mass blooming of weeds/herbs/grasses in the ground layer (ii) Coffee shrubs in the upper layer	600 m to swamps	Forest fallows, swampy forests, woody grasslands, woodlots, Invasive tree species, young fallows, hedgerows
	Naikesa	Simple agroforests	10–20	(i) Mass blooming of ruderal vegetations (ii) Coffee shrubs in the upper layer	1600 to swamps	Forest fallows, old fallows, grazing fields, shrublands, swamps
Kamuli	Namulekya	Multistrata complex agroforests	10–200	(i) Tin woody trees (ii) Tall herbs in lower layer (iii) Coffee shrubs in the upper layer (iv) Diverse indigenous shading trees	400 m to swamps	Swampy forests, eucalyptus plantations, young fallows, pine plantations

TABLE 1: Continued.

Cluster names	Study site names	Type of traditional agroforestry systems	Size range (ha) of the agroforest	Other vegetation characteristics of the traditional agroforests	Closeness or distance to water bodies	Dominant natural habitats, seminatural habitats, and vegetation types found within, around, and in the vicinity of sites
Kaweri	Luwunga	Large shaded coffee plantations	10–60	(i) Diverse shade tree species (ii) Mass blooming weeds/herbs in the ground layer	200 m to river channels	(i) Forest fragments in the vicinity of the coffee plantations, (ii) Presence of rivers and irrigation channels
	Nonve	Large sun coffee plantations	10–900	(i) Simple and scattered presence of native plant species in the coffee plantations	500 m to rivers	(i) Forest fragments in the vicinity of the coffee (ii) Presence of rivers and irrigation channels
Lugazi	Kasaku tea	Large sun tea plantations	50–750	(i) Mass blooming of weeds/herbs in the ground layer (ii) Tea shading trees	200 m to Swamps	Wood-shrub grasslands, swamps
	Sugar	Large sun sugar cane plantations	5–10	(i) Mass blooming of weeds/herbs in the ground layer	200 m to irrigation channels	Shrublands, irrigation channels
Mabira	Bulyasi	Complex forest-agroforest systems	10–400	(i) Mass blooming weeds/herbs (ii) Coffee shrubs, tall herbs, (iii) Indigenous	2000 m to streams	Eucalyptus plantations, forest fallows, young fallows, grazing fields, mabira large forest reserves
	Kinoni	Simple agroforests, homegardens	10–760	(i) Native medicinal plant species, (ii) Diverse shade trees (iii) Diverse fruit tree species (iv) Multistrata mass blooming weeds/herbs/grasses	8000 m to marshlands	Forest fallows, young fallows, old fallows, grazing fields
Masaka	Kasaala	Simple agroforests	10–100	(i) Coffee shrubs in the upper layer (ii) Simple shade tree species	12000 m to rivers	Young fallows, old fallows
	Katwadde	Simple agroforests	10–100	(i) Diverse tree species (ii) Presence of forest remnant trees	17000 m to rivers	Young fallows, hedgerows, grazing plots
	Kiwaala	Complex coffee-banana agroforests	10–980	(i) Multiple native shade tree stands (ii) Multistrata of blooming of weeds/herbs/grasses (iii) Forest remnant trees	12000 m to wetlands	Ecotones, forest fallows, old fallows, hedgerows, cattle pastures, woodlands, forest reserves, wetlands
	Mpugwe	Simple agroforests	10–200	(i) Dense native shade trees (ii) Mass blooming of weeds/herbs	18000 m to rivers	Forest remnants, young fallows, old fallows, grasslands, shrublands

TABLE 1: Continued.

Cluster names	Study site names	Type of traditional agroforestry systems	Size range (ha) of the agroforest	Other vegetation characteristics of the traditional agroforests	Closeness or distance to water bodies	Dominant natural habitats, seminatural habitats, and vegetation types found within, around, and in the vicinity of sites
Mpigi	Lukalu	Complex agroforests	10–600	(i) Mass blooming weeds/herbs in the ground layer	200 m to streams	Young fallows, cattle pastures, hedgerows, forest fallows, intact natural forest reserves
	Mpanga	Complex traditional agroforests	1100	(i) Mixture of coffee shrubs, tin woody trees, tall herbs, diverse fruit species	300 m to wetlands	Swamps, forest wetlands, young fallows, grazing fields, forest fallows, shrublands, forest reserves
	Kimuli	Multistrata complex agroforests	10–400	(i) Mass blooming weeds/herbs (ii) Dense native trees in the canopy layer	200 m to large wetlands	Ecotones, forest fallows, cattle pastures, grasslands, cleared forests, forest fallows, secondary forests, swamps, large wetlands
Nakaseke	Kyetume	Complex agroforests	10–400	(i) Mass blooming weeds/herbs (ii) Dense native trees in the canopy (iii) “Semi-forests” of coffee trees	2200 m to large wetlands	Woodlands, shade tree stands, young fallows, cattle pastures, woodlands, primary forests, secondary forests
	Lukumbi	Complex agroforests	10–200	(i) Mass blooming weeds/herbs (ii) Dense native trees in the canopy (iii) Forest remnant trees	3800 m to large swamps	Woodlands, young fallows, grazing fields, forest fallows, secondary forests, SEMUTO large wetlands
	Segalye	Complex agroforests	10–600	(i) Mass blooming weeds/herbs (ii) Dense native trees in the canopy (iii) Forest remnant trees	4890 m to large swamps	Old fallows, woodlands, degraded secondary forests, large woodlands

FIGURE 2: Location of Bukose, Namizi-east, Namizi-west, and Nawangoma study sites in Jinja district.

not be identified on spot were captured for laboratory identification. While sampling to both sides of the transect, caution was taken to sufficiently avoid double counting or recounting of individuals of a given species by walking in one direction and by not moving back to resample a species seen behind the surveyor. To avoid counting individuals and species more than once, they were released far away from the sampling belt (transect). Thus, during transect walks, specimens were not collected.

2.2.2. Hand-Netting Method. Hand-netting was carried out immediately after visual counts were finished, using an ordinary insect hand net. Hand-netting was conducted for 20 to 30 min per transect and involved sampling (“hand-netting”) all butterflies that could not be identified on-spot during visual censuses, at every patch of nectarine plants that could be found alongside the transect. Captured butterflies were counted. Majority of captures were released after field identification, doubtful specimens were collected in paper packets and taken to the laboratory for proper identification.

2.2.3. Banana Fruit-Bait Traps Method. Butterflies were captured in traps baited with mashed ripe bananas that had been fermenting in plastic buckets for 2 days. The bait was prepared three days prior to baiting and not replaced unless lost. Traps were made with local materials, based on the Van-Someron-Rydon trap design [12, 21]. Thus, the traps were cylinders of white nylon netting (125 cm high and 35 cm in diameter) sewn onto a frame of two metal rings, closed at the top and open at the bottom. The trap nets were 125 cm in height, minimizing the risk of escape once butterflies had entered. Traps were placed at about 100 m interval along transect lines. At each trap point, one trap was placed in sunny area while the other was hanged in a shaded habitat to maximize the chance of trapping species attracted by different habitat management in the agricultural landscapes. Each trap baited with two spoons of fermenting banana, was suspended 1.5–2 m above the ground. Traps placed in sunny or shaded environments were hanged on trees and shrub branches using a slingshot and weighted fishing line. Traps were installed preferably in the evenings between 16 h00 and 18 h00 and samples removed after 48 h. Overall, twenty-baited traps were set each sampling visit in each study site. During the untrapping process, butterflies in the traps were counted and few individuals of the same species were collected in glassine paper envelopes for identification in the laboratory at Makerere University, the rest of the specimens found alive were released after they being recorded.

Butterfly specimens were identified by consulting literature, nomenclature, and colored plates of butterflies and by using the reference collection available at Makerere University Zoology Museum. The taxonomic characteristics of butterflies were obtained from standard guides including (i) *Butterflies of Kenya* [22]; (ii) *“Butterflies of West Africa”* [23]; (iii) *“Butterflies of Uganda”* [24]. Identification of all voucher specimens was confirmed by a butterfly taxonomist (Mrs. Akite Perpertra) based at Makerere University Zoology museum. A collection of butterfly voucher specimens from the 26 study sites is deposited at the Zoology Museums, Makerere University. Butterfly collection permit in farmlands of Uganda was issued by the Uganda national council of Science and technology (UNCST). Butterflies were collected under an officially registered project in Uganda (Darwin project reference: 14-032).

2.3. Environmental Factors. A variety of “environmental factors” (land-uses, seminatural habitat, and natural habitats) are used as foraging/breeding habitats by diverse butterfly species in central Uganda. These “environmental factors” are likely influencing occurrence of different foraging butterfly species on transects. Concurrently with butterfly surveys, different land-uses and seminatural habitats that met within and in the vicinity of crop fields during transect walks were noted every sampling day in each study site. The size (ha) of the habitat was also recorded simultaneously to the registration of butterfly species and individuals visiting nectarine patches within the habitat/land use.

During transect walks, activities of different butterfly species on blooming crops were noted. In each study site

and in each habitat/land use, the number of plant species in bloom was recorded each sampling day in order to estimate the availability of nectarine resources for butterflies on a monthly basis. In addition, average climatic data (rainfall, temperature) for year 2006 was calculated using raw data from 4 meteorological stations located in the study zone for year 2006. Detailed information on meteorological data from the study region can also be obtained from the office of the prime minister, government of Uganda, meteorological department, Kampala, Uganda [7].

2.4. Butterfly Biodiversity Analysis. For the basic biodiversity analysis, the data from the three sampling methods were pooled to obtain total butterfly biodiversity per 2 ha transect per study site per sampling round as recommended [7]. In addition to personal field observations, data on butterfly functional groups were obtained from published records. The nomenclature of butterfly habitat associations and ecological group was adopted from Larsen [22, 23] and from Davenport [25]. Thus, every species recorded was assigned to one of the following ecological habitat categories: F = forest-dependent species; f/m = forest edge/woodland habitats and migratory specialist species; f = forest edge/woodland species; O = open habitat specialist species; O/m = open habitat/migratory species; S = swamp/wetland specialist species; W = widespread species; U = species of unknown (undescribed) habitat preference; W/m = widespread species and migratory species; m = migratory species. The proportion of the F and f species in a sample is an indication of the ecological state (habitat of good quality) of the habitat when working in forest habitats [19] and in similar agricultural matrices. For each ecological category, species richness and abundance were calculated using pooled data from the three sampling methods.

For the biodiversity analysis, species dominance (D) was calculated according to Buschni and Woiski [26]: $D = (\text{abundance of a species} / \text{total abundances recorded}) \times 100$. If $D > 5\%$, the species was termed a dominant species; if $2.5\% < D < 5\%$, the species was termed an accessory species or species of intermediate abundance, and if $D < 2.5\%$, the species was termed as an incidental species. Rare species (species represented by less than 5 individuals and or sampled from only one site) and unique species (species occurring with one individual: singleton, or with two individuals: doubleton) were noted whenever present per sample obtained each sampling round as recommended [26, 27].

Species richness was estimated by considering the number of butterfly species recorded each sampling round [27]. Total species recorded per study site was used to get the average since the interest was to detect the pattern. Butterfly faunal diversity was estimated by calculating the Evenness and the Shannon diversity indices as recommended [27].

Species accumulation curves, which plot the cumulative number of species (S) as a function of sampling effort, were used as recommended [27]. To determine the degree to which the sampling effort and protocol accurately reflected the butterfly community, species accumulation

curves were generated based on continuous samples obtained in each round of data collection as recommended [27]. Species accumulation and estimation curves were generated using the Jackknife1 estimator. Jackknife-1 was calculated using Microsoft Excel 2003 computer program following approaches described by [27].

The Sorensen similarity index [27, 28] was used to compare similarities among sampling methods. Sørensen's index of similarity (IS) was calculated using the following equation: $IS = [(2C/2C + A + B)] \times 100$, where C is the number of species in common between two treatments having A and B number of species, respectively. An IS value of 100 indicates that the two treatments contain the same number of species (complete overlap among sampling methods), whereas an IS value of 0 indicates that the two treatments have no common species (there is no similarity in community composition between sampling methods).

2.5. Statistical Data Analysis. All variables were tested for normality and the strongly skewed variables were transformed prior to analyses if necessary to meet the assumption of normality and homogeneity of variances. Variables expressed as percentages (%) were arcsine-square-root (+0.5) transformed and number of species or counts of individuals were $\ln(x + 1)$ transformed. However, when log transformation of the raw data was performed and if the data was still skewed, an appropriate nonparametric test was applied. Back-transformed data are reported.

The differences in butterfly individuals and species, evenness and diversity between the 26 study sites were tested with General Linear Model (GLM) analysis of variance (ANOVA) in Minitab release version 15. Where the GLM test indicated significant differences, post-hoc Fishers' least significant difference (LSD) test was used.

To find out whether large-scale fields supported rich and diverse butterfly communities compared to small-scale fields, the General Linear Model (GLM) was applied with Fisher's protected least significant difference (LSD) test for mean separation at 5% probability.

Data on butterfly attraction to different habitat/land-use types found in the 26 study sites was skewed even after transformation. Therefore, to identify best habitat/land-use types for butterflies inhabiting farmlands, a nonparametric test was applied to investigate the effect of habitat types on the richness and abundance of butterflies.

The relationships of foraging butterfly species and "environmental factors" were explored using CANOCO program, version 4.5 [29]. A unimodal direct gradient analysis of partial canonical correspondence analysis (CCA) was used to relate the variation of butterfly communities to environmental variables. Different land-uses and seminatural habitats recorded on transects were put in the data matrix of independent environmental factors, whereas recorded foraging butterfly species were grouped in the data matrix of dependent variables. The ordination analysis was based on all butterfly species that were entered in the model with 10 environmental factors. Environmental variables were selected using manual forward selection. Under a

reduced model for the canonical axes (499 randomizations), Monte Carlo permutation tests were used to assess statistical significance of the association (linear relationship) between butterfly community species composition and environmental factors. Results from the CCA produce eigenvalues that are used to describe how much variance is explained by each ordination axis, thus measuring the importance of each axis. Whenever the significance of the whole ordination was obtained, a forward stepwise method was used to determine which environmental variables were correlated to axes and explained variation in butterfly species composition. A test for significance of correlation of environmental factors with the 4 different axes was conducted using Spearman rank of correlation. To illustrate the relationships between environmental variables and species, biplots of the respective partial CCA were produced.

3. Results

3.1. Butterfly Assemblages. Overall 56315 butterfly individuals belonging 6 families, 15 subfamilies, 24 tribes, 95 genera, and 331 species (Table 2) were sampled across the 26 study sites. There were 120 singleton species, 80 doubleton species, and 59 rare species. The highest estimated species richness was captured by hand nets (where Jackknife-1 revealed a very steep final slope). The species accumulation curve was relatively steep, not reaching an asymptote in hand net and transect counts although beginning to reach a plateau by round four in banana-bait trapping method. Similarly, the overall species accumulation curves for butterflies did not saturate. Because the curve did not saturate, this indicated that not all species of butterfly present in central Uganda were sampled. Overall, the total number of observed species was 331 while Jackknife1 predicted a total of 360 species. This indicates that 91.2% (331 of 360 estimated species) of the species present in the study area during the period of study were sampled.

In this study, the highest species richness was captured in hand nets (Figure 3). Most (75% of total individuals) butterflies were recorded through line transect counts and very relatively individuals were captured by hand net (19%) and banana-bait trap (6%). Hence, hand-net and banana-baits methods sampled statistically ($P > 0.05$) similar butterfly individuals.

There were differences between average similarity index values (Sorensen similarity index) of species shared between the three sampling methods. The percentage of shared species (measured here as % of similarity in species composition) between the sampling methods was highest between hand net and transects counts (41.9%) followed by hand net and banana-bait traps (31.8%) and least between banana-baits and transect counts (21.5%). These results also indicate that use of multiple techniques can considerably increase the number of species.

The abundance of different butterfly taxa varied among sampling methods. Overall, the most abundant species was *Bicyclus safitza* (14.5%) followed by *Acraea acerata* (6.3%), *Catopsilia florella* (6.5%), and *Junonia sophia* (6.1%). Also,

the most abundant genus was *Bicyclus* (21.6%) followed by *Acraea* (13%), *Junonia* (6.1%), and *Eurema* (5.7%). For the fruit bait traps, *Bicyclus safitza* (23.3%), followed by *Eurytela drope* (6.4%), were the most abundant species. The most abundant genus trapped using banana-bait trap was *Bicyclus* (45.2%) followed by *Eurytela* (8.3%), *Acraea* (5.9%), *Junonia* (5.7%), and *Neptidopsis* (4.5%).

Most (44%) of the 331 species sampled were “forest-dependent species,” followed by widespread species (31.4%) and open habitat specialists (13%) (Table 2). Species belonging to the other ecological trait categories constituted less than 12% of the total species sampled. Forest edge/woodland had the least proportion of species sampled (Table 2).

Variation in butterfly abundance, species richness, and diversity between the 26 study sites within the different sampling methods were striking (Table 3). The highest abundance was associated with Kiweebwa study site whereas the site with lowest abundance was Nonve (Table 3). The highest butterfly species richness was found in Lukalu and the lowest in Nonve study sites (Table 3). The highest diversity index value was found in Kimuli study site and the lowest in Nonve study site (Table 3). There was no clear pattern for the land-use intensity gradient. Study sites located in regions with low land-use intensity were not necessarily species study sites that supported high species richness. For example, the highest species richness was recorded in Lukalu site that is located in region with medium land-use intensity. However, study sites with very high land use intensity were the least species-rich sites: Nonve and Luwunga (Table 3).

The pattern of butterfly species richness and abundance varied across sampling rounds and sampling methods. Average butterfly species richness ranged from 19 to 32 species across sampling rounds, with the highest richness occurring during the first round and the least in the fifth round of data collection. Butterfly abundance was higher in the first and second sampling rounds than in the rest of the rounds. Overall, butterfly species richness and abundance varied seasonally, with more species and higher densities in the rainy seasons (wet months) compared with the dry season (dry months).

3.2. Environmental Factors Determining Occurrence of Different Species. Butterfly community was significantly related to environmental factors measured (Figure 4; Table 4: CCA; sum of all canonical variables = 1.635; $F = 1.286$, $P = 0.01603$ for all canonical axes). The first, second, third, and fourth axes explain 26.6%, 24.2%, 23.2%, and 20.4% of the variance, respectively, in the model. The correlation of the environmental variables with the axes is summarized in Table 5. Few environmental factors significantly correlated with axes (Table 5). Axis 3 had a high loading for the most determinant factors of butterflies in farmland of central Uganda: small-scale agroforestry fields with fruit tree species, large coffee plantations in the margins of native forest fragments, swampy habitats, reclaimed wetlands, stream-edges, Eucalyptus/Pine plantations, woodlands, grasslands, large tea plantations in vicinity of wetlands/swamps, small-scale monoculture/polyculture fields of annual/biannual crops,

TABLE 2: Systematic list of butterfly species collected from farmlands of central Uganda in 2006. The species are arranged per family, subfamily, and par ecological category.

Family	Subfamily	Species	E-cat
Riodinidae	Nemobiinae	<i>Abisara neavei neavei</i> (Riley)	FDS
Hesperiidae	Hesperiinae	<i>Acleros mackenii olaus</i> (Plötz)	FEW
Nymphalidae	Heliconiinae	<i>Acraea lycoa</i> (Godart)	N
Nymphalidae	Heliconiinae	<i>Acraea acerata</i> (Hewitson)	WSS
Nymphalidae	Heliconiinae	<i>Acraea acrita</i> (Hewitson)	N
Nymphalidae	Heliconiinae	<i>Acraea aganice</i> (Hewitson)	SWSS
Nymphalidae	Heliconiinae	<i>Acraea alicia</i> (Sharpe)	N
Nymphalidae	Heliconiinae	<i>Acraea asboloplintha</i> (Karsch)	SWSS
Nymphalidae	Heliconiinae	<i>Acraea baxteri philos</i>	FEW
Nymphalidae	Heliconiinae	<i>Acraea bonasia bonasia</i>	FDS
Nymphalidae	Heliconiinae	<i>Acraea boopis ama</i> (Pierre)	FDS
Nymphalidae	Heliconiinae	<i>Acraea cabira</i> (Hopffer)	FEW
Nymphalidae	Heliconiinae	<i>Acraea egina egina</i> (Cramer)	WSS
Nymphalidae	Heliconiinae	<i>Acraea encedon encedon</i> (Linnaeus)	WSS
Nymphalidae	Heliconiinae	<i>Acraea eponina eponina</i> (Cramer)	WSS
Nymphalidae	Heliconiinae	<i>Acraea jodutta jodutta</i> (Fabricius)	FDS
Nymphalidae	Heliconiinae	<i>Acraea johnstoni johnstoni</i> (Godman)	FEW
Nymphalidae	Heliconiinae	<i>Acraea leucographa</i> (Ribbe)	FDS
Nymphalidae	Heliconiinae	<i>Acraea macarista macarista</i> (Sharpe)	FDS
Nymphalidae	Heliconiinae	<i>Acraea natalica natalica</i> (Boisduval)	N
Nymphalidae	Heliconiinae	<i>Acraea neobule</i> (Doubleday)	WSS
Nymphalidae	Heliconiinae	<i>Acraea penelope vitrea</i> (Eltringham)	FDS
Nymphalidae	Heliconiinae	<i>Acraea perenna perenna</i> (Doubleday)	FEW
Nymphalidae	Heliconiinae	<i>Acraea pharsalus pharsalus</i> (Ward)	N
Nymphalidae	Heliconiinae	<i>Acraea poggei nelson</i> (Grose-Smith & Kirby)	FDS
Nymphalidae	Heliconiinae	<i>Acraea pudorella pudorella</i> (Aurivillius)	N
Nymphalidae	Heliconiinae	<i>Acraea quirinalis</i> (Grose-Smith)	FDS
Nymphalidae	Heliconiinae	<i>Acraea semivitrea</i> (Aurivillius)	FDS
Nymphalidae	Heliconiinae	<i>Acraea servona</i> (Godart)	FDS
Nymphalidae	Heliconiinae	<i>Acraea sotikensis</i> (Sharpe)	FDS
Nymphalidae	Heliconiinae	<i>Acraea uvui uvui</i> (Grose-Smith)	FEW
Nymphalidae	Heliconiinae	<i>Acraea ventura ochrascens</i> (Hewitson)	SWSS
Nymphalidae	Heliconiinae	<i>Acraea viviana</i> (Staudinger)	FEW
Nymphalidae	Heliconiinae	<i>Acraea zetes zetes</i> (Linnaeus)	WSS
Nymphalidae	Heliconiinae	<i>Acraea zonata</i> (Hewitson)	N
Lycaenidae	Polyommatainae	<i>Actizera lucida lucida</i> (Trimen)	WSS
Lycaenidae	Polyommatainae	<i>Actizera stellata</i> (Trimen)	OHPS
Lycaenidae	Lipteninae	<i>Alaena picata</i> (Sharpe)	N
Lycaenidae	Theclinae	<i>Aloeides conradi</i> (Aurivillius)	N
Nymphalidae	Danainae	<i>Amauris albimaculata</i> (Butler)	FDS
Nymphalidae	Danainae	<i>Amauris hecate hecate</i> (Butler)	FDS
Nymphalidae	Danainae	<i>Amauris niavius niavius</i> (Linnaeus)	WSS
Nymphalidae	Danainae	<i>Amauris tartarea</i> (Mabille)	FEW
Nymphalidae	Danainae	<i>Amauris ochlea</i> (Boisduval)	FEW
Nymphalidae	Charaxinae	<i>Antanartia delius delius</i> (Drury)	FDS
Lycaenidae	Polyommatainae	<i>Anthene amarah amarah</i> (Guérin-Ménéville)	OHPS
Lycaenidae	Polyommatainae	<i>Anthene butleri</i> (Oberthür)	WSS
Lycaenidae	Polyommatainae	<i>Anthene kampala</i>	FEW
Lycaenidae	Polyommatainae	<i>Anthene larydas</i> (Cramer)	FEW
Lycaenidae	Polyommatainae	<i>Anthene lunulata</i> (Trimen)	FEW

TABLE 2: Continued.

Family	Subfamily	Species	E-cat
Lycaenidae	Polyommatainae	<i>Anthene schoutedeni</i> (Huelstaert)	FDS
Pieridae	Pierinae	<i>Appias sylvia ugandensis</i> (Bernardi)	FDS
Nymphalidae	Biblidinae	<i>Ariadne albifascia</i> (Joicey & Talbot)	FDS
Nymphalidae	Biblidinae	<i>Ariadne enotrea suffusa</i> (Joicey & Talbot)	FEW
Nymphalidae	Biblidinae	<i>Ariadne pangenstecheri</i> (Suffert)	FEW
Hesperiidae	Hesperiinae	<i>Artitropa milleri milleri</i> (Holland)	WSS
Lycaenidae	Theclinae	<i>Axiocerses harpax ugandana</i> (Clench)	N
Lycaenidae	Polyommatainae	<i>Azanus natalensis</i> (Trimen)	MS
Lycaenidae	Polyommatainae	<i>Azanus ubaldus</i> (Cramer)	MS
Pieridae	Pierinae	<i>Belenois creona</i> (Cramer)	N
Pieridae	Pierinae	<i>Belenois raffrayi extendens</i> (Joicey & Talbot)	FDS
Pieridae	Pierinae	<i>Belenois solilucus</i> (Butler)	FEW
Pieridae	Pierinae	<i>Belenois aurota</i> (Fabricius)	MS
Pieridae	Pierinae	<i>Belenois creona severina</i> (Stol)	MS
Pieridae	Pierinae	<i>Belenois subeida sylvander</i> (Grose-Smith)	N
Pieridae	Pierinae	<i>Belenois theora theora</i> (Doubleday)	FEW
Pieridae	Pierinae	<i>Belenois thysa</i> (Hopffer)	FEW
Nymphalidae	Satyrinae	<i>Bicyclus buea</i> (Strand)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus funebris</i> (Guérin-Ménéville)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus mollitia</i>	SWSS
Nymphalidae	Satyrinae	<i>Bicyclus safitza safitza</i> (Hewitson)	WSS
Nymphalidae	Satyrinae	<i>Bicyclus abnormis</i> (Dudgeon)	WSS
Nymphalidae	Satyrinae	<i>Bicyclus anynana anynana</i> (Butler)	OHPS
Nymphalidae	Satyrinae	<i>Bicyclus campina ocelligera</i> (Butler)	N
Nymphalidae	Satyrinae	<i>Bicyclus campinus</i> (Aurivillius)	SWSS
Nymphalidae	Satyrinae	<i>Bicyclus campus</i> (Karsch)	N
Nymphalidae	Satyrinae	<i>Bicyclus dentatus</i> (Sharpe)	FEW
Nymphalidae	Satyrinae	<i>Bicyclus ena</i> (Hewitson)	OHPS
Nymphalidae	Satyrinae	<i>Bicyclus evadne elionas</i> (Hewitson)	N
Nymphalidae	Satyrinae	<i>Bicyclus golo</i> (Aurivillius)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus hewitsoni</i> (Doumet)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus istaris</i> (Plötz)	FEW
Nymphalidae	Satyrinae	<i>Bicyclus jefferyi</i> (Fox)	FEW
Nymphalidae	Satyrinae	<i>Bicyclus kenia</i> (Rogernhofer)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus mandanes</i> (Hewitson)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus mollitia</i> (Karsch)	N
Nymphalidae	Satyrinae	<i>Bicyclus sandace</i> (Hewitson)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus saussurei saussurei</i> (Condamin)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus smithi smithi</i> (Aurivillius)	FDS
Nymphalidae	Satyrinae	<i>Bicyclus sophrosyne sophrosyne</i> (Plötz)	SWSS
Nymphalidae	Satyrinae	<i>Bicyclus</i> sp.1	N
Nymphalidae	Satyrinae	<i>Bicyclus</i> sp.2	N
Nymphalidae	Satyrinae	<i>Bicyclus vulgaris</i> (Butler)	WSS
Hesperiidae	Hesperiinae	<i>Borbo fatuellus fatuellus</i> (Hopffer)	WSS
Hesperiidae	Hesperiinae	<i>Borbo holtzii</i> (Plötz)	OHPS
Hesperiidae	Hesperiinae	<i>Borbo kaka</i> (Evans)	FDS
Nymphalidae	Biblidinae	<i>Byblia anvatara acheloia</i> (Wallengren)	MS
Nymphalidae	Biblidinae	<i>Byblia ilithyia</i> (Drury)	N
Lycaenidae	Polyommatainae	<i>Cacyreus palemon palemon</i> (Stoll)	OHPS
Lycaenidae	Hesperiinae	<i>Caenides luehderi laura</i> (Evans)	N
Pieridae	Coliadinae	<i>Catopsilia florella</i> (Fabricius)	MS

TABLE 2: Continued.

Family	Subfamily	Species	E-cat
Hesperiidae	Pyrginae	<i>Celaenorrhinus galenus</i> (Fabricius)	FDS
Hesperiidae	Pyrginae	<i>Celaenorrhinus ovalis</i> (Evans)	N
Hesperiidae	Pyrginae	<i>Celaenorrhinus proxima proxima</i> (Mabille)	FDS
Nymphalidae	Charaxinae	<i>Charaxes acuminatus</i> (Thurau)	FDS
Nymphalidae	Charaxinae	<i>Charaxes anticlea suna</i> (van Someren)	FEW
Nymphalidae	Charaxinae	<i>Charaxes aubyni ecketti</i>	N
Nymphalidae	Charaxinae	<i>Charaxes bipunctatus ugandensis</i> (van Someren)	FDS
Nymphalidae	Charaxinae	<i>Charaxes brutus</i> (Cramer)	FEW
Nymphalidae	Charaxinae	<i>Charaxes chepalungu</i> (van Someren)	N
Nymphalidae	Charaxinae	<i>Charaxes contrarius</i> (Weymer)	N
Nymphalidae	Charaxinae	<i>Charaxes dilutusngonga</i>	FDS
Nymphalidae	Charaxinae	<i>Charaxes etesipe</i> (Rothschild)	FEW
Nymphalidae	Charaxinae	<i>Charaxes ethalion nyanzae</i> (de Boisduval)	WSS
Nymphalidae	Charaxinae	<i>Charaxes etheocles</i> (van Someren & Jackson)	FDS
Nymphalidae	Charaxinae	<i>Charaxes etheocles etheocles</i> (Cramer)	FDS
Nymphalidae	Charaxinae	<i>Charaxes eupale latimargo</i> (Joicey & Talbot)	N
Nymphalidae	Charaxinae	<i>Charaxes guderiana rabaiensis</i> (Poulton)	N
Nymphalidae	Charaxinae	<i>Charaxes hildebrandti hildebrandti</i> (Dewitz)	FDS
Nymphalidae	Charaxinae	<i>Charaxes lactetinctus lactetinctus</i> (Karsch)	OHPS
Nymphalidae	Charaxinae	<i>Charaxes lucretius maximus</i> (van Someren)	FDS
Nymphalidae	Charaxinae	<i>Charaxes nobilis claudaei</i> (le Moult)	FDS
Nymphalidae	Charaxinae	<i>Charaxes numenes numenes</i> (Hewitson)	FEW
Nymphalidae	Charaxinae	<i>Charaxes plantroui</i> (Minig)	N
Nymphalidae	Charaxinae	<i>Charaxes pleione</i> (Godart)	N
Nymphalidae	Charaxinae	<i>Charaxes protoclea azota</i> (Hewitson)	FEW
Nymphalidae	Charaxinae	<i>Charaxes smaragdalis butleri</i> (Rothschild)	FDS
Nymphalidae	Charaxinae	<i>Charaxes tiridates tiridates</i> (Cramer)	FDS
Nymphalidae	Charaxinae	<i>Charaxes varanes vologeses</i> (Mabille)	WSS
Nymphalidae	Charaxinae	<i>Charaxes viola picta</i> (van Someren & Jackson)	OHPS
Nymphalidae	Charaxinae	<i>Charaxes xiphares</i>	FDS
Nymphalidae	Charaxinae	<i>Charaxes zoolina zoolina</i> (Westwood)	OHPS
Lycaenidae	Polyommatainae	<i>Chilades kedonga</i> (Grose-Smith)	OHPS
Hesperiidae	Hesperiinae	<i>Chondrolepsis niveicornis niveicornis</i> (Plötz)	FDS
Lycaenidae	Lipteninae	<i>Cocyreus lingens</i>	N
Hesperiidae	Coeliadinae	<i>Coeliades anchises anchises</i> (Gerstäcker)	MS
Hesperiidae	Coeliadinae	<i>Coeliades chalybe</i> (Westwood)	FDS
Hesperiidae	Coeliadinae	<i>Coeliades forestan forestan</i> (Stoll)	WSS
Hesperiidae	Coeliadinae	<i>Coeliades hanno</i>	FDS
Nymphalidae	Satyrinae	<i>Coenyropsis carcassoni</i> (Kielland)	OHPS
Pieridae	Coliadinae	<i>Colias electo pseudohecate</i> (Berger)	MS
Pieridae	Pierinae	<i>Colotis antevippe zera</i> (Lucas)	OHPS
Pieridae	Pierinae	<i>Colotis aurigineus</i> (Butler)	WSS
Pieridae	Pierinae	<i>Colotis chrysonome</i> (Klug)	OHPS
Pieridae	Pierinae	<i>Colotis danae</i> (Fabricius)	WSS
Pieridae	Pierinae	<i>Colotis euippe</i> (Linnaeus)	WSS
Pieridae	Pierinae	<i>Colotis venosus</i> (Staudinger)	OHPS
Lycaenidae	Polyommatainae	<i>Cupidopsis cissus</i> (Godart)	WSS
Lycaenidae	Polyommatainae	<i>Cupidopsis jobates jobates</i> (Hopffer)	WSS
Nymphalidae	Limenitidinae	<i>Cymothoe elgesta confusa</i> (Aurivillius)	N
Nymphalidae	Nymphalinae	<i>Cymothoe lurida butleri</i> (Grünberg)	FDS
Nymphalidae	Nymphalinae	<i>Cymothoe althea althea</i>	N

TABLE 2: Continued.

Family	Subfamily	Species	E-cat
Nymphalidae	Limenitidinae	<i>Cymothoe herminia johnstoni</i> (Butler)	FDS
Nymphalidae	Limenitidinae	<i>Cymothoe hobarti hobarti</i> (Butler)	FDS
Nymphalidae	Limenitidinae	<i>Cymothoe weymeri weymeri</i> (Suffert)	N
Nymphalidae	Danainae	<i>Danaus chrysippus chrysippus</i> (Linnaeus)	MS
Nymphalidae	Danainae	<i>Danaus dorripus</i> (Klug)	MS
Pieridae	Pierinae	<i>Dixeia orbona vidua</i> (Butler)	WSS
Pieridae	Pierinae	<i>Dixeia pigea</i> (Boisduval)	WSS
Pieridae	Liphyrinae	<i>Dixeia spilleri spilleri</i> (Spiller)	N
Lycaenidae	Polyommatainae	<i>Eicochrysops messapus</i> (Bethune&Baker)	N
Lycaenidae	Polyommatainae	<i>Eicochrysops Hippocrates</i> (Fabricius)	N
Lycaenidae	Polyommatainae	<i>Eicochrysops masai</i> (Bethune-Baker)	OHPS
Hesperiidae	Pyrginae	<i>Eretis lugens</i> (Rogenhofer)	WSS
Pieridae	Coliadinae	<i>Eronia cleodora</i> (Hubne)	OHPS
Lycaenidae	Polyommatainae	<i>Euchrysops nilotica</i> (Aurivillius)	N
Lycaenidae	Polyommatainae	<i>Euchrysops malathana</i> (Boisduval)	OHPS
Lycaenidae	Polyommatainae	<i>Euchrysops osiris</i> (Hopffer)	WSS
Lycaenidae	Polyommatainae	<i>Euchrysops subpallida</i> (Bethune-Baker)	N
Nymphalidae	Nymphalinae	<i>Euphaedra preussi preussi</i> (Staudinger)	N
Pieridae	Coliadinae	<i>Eurema brigitta brigitta</i> (Stoll)	MS
Pieridae	Coliadinae	<i>Eurema desjardinsi oberthuri</i> (Mabille)	MS
Pieridae	Coliadinae	<i>Eurema floricola orientis</i> (Butler)	FDS
Pieridae	Coliadinae	<i>Eurema hecabe solifera</i> (Butler)	MS
Pieridae	Coliadinae	<i>Eurema regularis regularis</i> (Butler)	WSS
Pieridae	Coliadinae	<i>Eurema senegalensis</i> (Boisduval)	FDS
Nymphalidae	Nymphalinae	<i>Eurytela dryope angulate</i> (Aurivillius)	WSS
Nymphalidae	Nymphalinae	<i>Eurytela alinda</i> (Mabille)	N
Nymphalidae	Nymphalinae	<i>Eurytela hiarbas lita</i> (Rothschild & Jordan)	FEW
Hesperiidae	Hesperiinae	<i>Freyeria trochylus</i> (Freyer)	WSS
Hesperiidae	Hesperiinae	<i>Gegenes hottentota</i> (Latreille)	OHPS
Hesperiidae	Hesperiinae	<i>Gegenes niso brevicornis</i> (Plötz)	N
Hesperiidae	Hesperiinae	<i>Gegenes pumilio gambica</i> (Mabille)	OHPS
Nymphalidae	Satyrinae	<i>Gnophodes betsimena diversa</i> (Trimen)	FDS
Papilionidae	Papilioninae	<i>Graphium policenes</i> (Cramer)	N
Papilionidae	Papilioninae	<i>Graphium antheus</i>	FEW
Papilionidae	Papilioninae	<i>Graphium leonidas Leonidas</i> (Fabricius)	MS
Papilionidae	Papilioninae	<i>Graphium polistratus</i> (Grose-smith)	FEW
Nymphalidae	Satyrinae	<i>Hallelesis asochis</i>	N
Nymphalidae	Satyrinae	<i>Hallelesis halyma</i>	N
Nymphalidae	Satyrinae	<i>Halocerina angulata</i>	N
Nymphalidae	Nymphalinae	<i>Hamanumida daedalus</i> (Fabricius)	WSS
Nymphalidae	Satyrinae	<i>Henotesia peitho</i> (Plötz)	WSS
Nymphalidae	Satyrinae	<i>Henotesia perpicua</i> (Trimen)	OHPS
Nymphalidae	Nymphalinae	<i>Hypokoelates ugandae</i> (Talbot)	N
Nymphalidae	Nymphalinae	<i>Hypolimnas misippus</i> (Linnaeus)	MS
Nymphalidae	Nymphalinae	<i>Hypolimnas salmacis magnifica</i> (Rothschild)	FDS
Lycaenidae	Theclinae	<i>Hypolycaena hatita ugandae</i> (Sharpe)	FDS
Lycaenidae	Theclinae	<i>Iolaus poultoni</i> (Riley)	FDS
Nymphalidae	Heliconiinae	<i>Issoria hanningtoni jeanneli</i> (Bernardi)	FEW
Nymphalidae	Nymphalinae	<i>Junonia natalica</i> (Felder)	FEW
Nymphalidae	Nymphalinae	<i>Junonia chorimene</i> (Guérin-Ménéville)	OHPS
Nymphalidae	Nymphalinae	<i>Junonia eonone eonone</i> (Linnaeus)	WSS

TABLE 2: Continued.

Family	Subfamily	Species	E-cat
Nymphalidae	Nymphalinae	<i>Junonia hierta cebrene</i> (Trimen)	MS
Nymphalidae	Nymphalinae	<i>Junonia orithya madagascariensis</i> (Guenee)	N
Nymphalidae	Nymphalinae	<i>Junonia sophia infracta</i> (Butler)	N
Nymphalidae	Nymphalinae	<i>Junonia stygia gregorii</i> (Butler)	FEW
Nymphalidae	Nymphalinae	<i>Junonia terea elgiva</i> (Drury)	WSS
Nymphalidae	Nymphalinae	<i>Junonia westermanni suffusa</i> (Rothschild & Jordan)	FDS
Hesperiidae	Hesperiinae	<i>Kedestes rogersi</i> (Druce)	OHPS
Lycaenidae	Polyommatainae	<i>Lepidochrysops desmondi</i> (Stempffer)	N
Lycaenidae	Polyommatainae	<i>Lepidochrysops elgonae</i> (Stempffer)	N
Lycaenidae	Polyommatainae	<i>Lepidochrysops cf jansei</i> (van Someren)	WSS
Lycaenidae	Polyommatainae	<i>Lepidochrysops kitale</i> (Stempffer)	N
Lycaenidae	Polyommatainae	<i>Lepidochrysops parsimon parsimon</i> (Fabricius)	OHPS
Pieridae	Pierinae	<i>Leptosia alcesta inalcesta</i> (Bernardi)	WSS
Pieridae	Pierinae	<i>Leptosia nupta nupta</i> (Butler)	FDS
Pieridae	Pierinae	<i>Leptosia wigginsi</i> (Dixey)	FDS
Nymphalidae	Libytheinae	<i>Libythea labdacca</i> (Westwood)	MS
Lycaenidae	Lipteninae	<i>Liptena xanthostola xantha</i> (Grose-Smith)	N
Nymphalidae	Nymphalinae	<i>Mallika jacksoni</i> (Sharpe)	OHPS
Nymphalidae	Satyrinae	<i>Melanitis leda</i> (Linnaeus)	WSS
Lycaenidae	Lipteninae	<i>Mimacraea krausei</i>	N
Lycaenidae	Lipteninae	<i>Mimacraea marshalli</i> (Trimen)	FEW
Hesperiidae	Hesperiinae	<i>Monza alberti</i> (Holland)	FDS
Hesperiidae	Hesperiinae	<i>Monza cretacea</i> (Snellen)	WSS
Pieridae	Pierinae	<i>Mylothris aburi</i> (Collins & Larsen)	N
Pieridae	Pierinae	<i>Mylothris agathina</i> (Cramer)	WSS
Pieridae	Pierinae	<i>Mylothris chloris clarissa</i> (Butler)	WSS
Pieridae	Pierinae	<i>Mylothris continua continua</i> (Aurivillius)	FDS
Pieridae	Pierinae	<i>Mylothris hilara</i> (Karsch)	FDS
Pieridae	Pierinae	<i>Mylothris ochracea</i> (Aurivillius)	N
Pieridae	Pierinae	<i>Mylothris sjoestedti sjoestedti</i> (Aurivillius)	FDS
Lycaenidae	Theclinae	<i>Myrina dermaptera nyasae</i> (Talbot)	OHPS
Pieridae	Pierinae	<i>Nepheronia argia</i> (Fabricius)	FDS
Pieridae	Pierinae	<i>Nepheronia pharis silvanus</i> (Stoneham)	FDS
Pieridae	Pierinae	<i>Nepheronia thalassina</i> (de Boisduval)	FEW
Nymphalidae	Nymphalinae	<i>Neptidopsis fulgurata</i> (Rothschild & Jordan)	N
Nymphalidae	Nymphalinae	<i>Neptidopsis ophione nucleate</i> (Mabille)	FEW
Nymphalidae	Limenitidinae	<i>Neptis alta</i> (Overlaet)	FDS
Nymphalidae	Limenitidinae	<i>Neptis carcassoni</i> (van Son)	N
Nymphalidae	Limenitidinae	<i>Neptis clareii</i> (Aurivillius)	FDS
Nymphalidae	Limenitidinae	<i>Neptis jordani</i> (Neave)	N
Nymphalidae	Limenitidinae	<i>Neptis katama</i> (Collins&Larsen)	N
Nymphalidae	Limenitidinae	<i>Neptis kiriakoffi</i> (Overlaet)	WSS
Nymphalidae	Limenitidinae	<i>Neptis laeta</i> (Overlaet)	WSS
Nymphalidae	Limenitidinae	<i>Neptis melicerta melicerta</i> (Hewitson)	FDS
Nymphalidae	Limenitidinae	<i>Neptis metella metella</i> (Doubleday)	FEW
Nymphalidae	Limenitidinae	<i>Neptis morosa</i> (Overlaet)	WSS
Nymphalidae	Limenitidinae	<i>Neptis nemetes nemetes</i> (Hewitson)	FEW
Nymphalidae	Limenitidinae	<i>Neptis occidentalis occidentalis</i> (Rothschild)	FDS
Nymphalidae	Limenitidinae	<i>Neptis ochracea milbraedi</i> (Gaede)	FDS
Nymphalidae	Limenitidinae	<i>Neptis penningtoni</i>	N
Nymphalidae	Limenitidinae	<i>Neptis poultoni</i> (Eltringham)	FDS

TABLE 2: Continued.

Family	Subfamily	Species	E-cat
Nymphalidae	Limenitidinae	<i>Neptis saclava marpessa</i> (Hopffer)	WSS
Nymphalidae	Limenitidinae	<i>Neptis strigata</i> (Aurivillius)	FDS
Nymphalidae	Limenitidinae	<i>Neptis woodwardi woodwardi</i> (Sharpe)	FDS
Lycaenidae	Polyommatainae	<i>Oboronia punctatus</i>	N
Lycaenidae	Lipteninae	<i>Ornipholidotos peucetia peucedata</i> (Grose-Smith)	FDS
Papilionidae	Papilioninae	<i>Papilio bromius</i> (Suffert)	FEW
Papilionidae	Papilioninae	<i>Papilio dardanus polytropus</i> (Brown)	WSS
Papilionidae	Papilioninae	<i>Papilio demodocus</i> (Esper)	MS
Papilionidae	Papilioninae	<i>Papilio lormieri</i>	FDS
Papilionidae	Papilioninae	<i>Papilio nireus lyaeus</i> (Doubleday)	FEW
Papilionidae	Papilioninae	<i>Papilio nobilis</i> (Rogenhofer)	FDS
Papilionidae	Papilioninae	<i>Papilio ophidicephalus</i> (Oberthür)	N
Papilionidae	Papilioninae	<i>Papilio phorcas</i> (Cramer)	FDS
Papilionidae	Papilioninae	<i>Papilio zoroastres joiceyi</i> (Gabriel)	FDS
Papilionidae	Hesperinae	<i>Paracleros biguttulus</i> (Mabille)	FEW
Hesperiidae	Hesperinae	<i>Pardaleodes incerta</i> (Snellen)	FDS
Hesperiidae	Hesperinae	<i>Pardaleodes sator pusiella</i> (Mabille)	FDS
Nymphalidae	Heliconiinae	<i>Pardopsis punctatissima</i> (Boisduval)	WSS
Lycaenidae	Lipteninae	<i>Pentila tachyroides tachyroides</i> (Dewitz)	N
Lycaenidae	Lipteninae	<i>Pentila pauli clarensis</i> (Neave)	N
Nymphalidae	Heliconiinae	<i>Phalanta phalantha</i> (Rothschild & Jordan)	MS
Pieridae	Pierinae	<i>Pinacopteryx eriphia melanarge</i> (Butler)	OHPS
Pieridae	Pierinae	<i>Pontia helice johnstoni</i> (Crowley)	MS
Nymphalidae	Nymphalinae	<i>Precis antilope</i> (Feishamel)	OHPS
Nymphalidae	Nymphalinae	<i>Precis archesia</i> (Cramer)	OHPS
Nymphalidae	Nymphalinae	<i>Precis ceryne ceryne</i> (Boisduval)	SWSS
Nymphalidae	Nymphalinae	<i>Precis coelestina</i>	FEW
Nymphalidae	Nymphalinae	<i>Precis octavia sesamus</i> (Trimen)	WSS
Nymphalidae	Nymphalinae	<i>Precis tugela</i> (Trimen)	FEW
Hesperiidae	Hesperinae	<i>Prosopalpus debilis</i> (Evans)	N
Hesperiidae	Hesperinae	<i>Protonotomorphia temora</i>	N
Nymphalidae	Nymphalinae	<i>Pseudacraea eurytus eurytus</i> (Linnaeus)	FDS
Nymphalidae	Nymphalinae	<i>Pseudacraea lucretia protracta</i> (Cramer)	FEW
Nymphalidae	Nymphalinae	<i>Pseudacraea boisduvali</i> (Doubleday)	N
Nymphalidae	Nymphalinae	<i>Pseudargynnis hegemon</i> (Godart)	FEW
Nymphalidae	Nymphalinae	<i>Pseudacraea lucretia expansa</i> (Butler)	N
Nymphalidae	Nymphalinae	<i>Salamis cacta cacta fbricius</i>	FDS
Nymphalidae	Nymphalinae	<i>Salamis parhassus</i> (Drury)	FEW
Nymphalidae	Nymphalinae	<i>Sallya boisduvali</i> (Wallengren)	MS
Nymphalidae	Nymphalinae	<i>Sallya garega garega</i> (Karsch)	MS
Nymphalidae	Nymphalinae	<i>Sallya natalensis</i> (Boisduval)	MS
Nymphalidae	Nymphalinae	<i>Sallya occidentalis occidentalis</i> (Mabille)	MS
Nymphalidae	Nymphalinae	<i>Sallya umbrina</i> (Karsch)	MS
Hesperiidae		<i>Sarangesa laelius</i> (Mabille)	WSS
Lycaenidae	Pyrginae	<i>Liptena maculata</i> (Mabille)	OHPS
Hesperiidae	Pyrginae	<i>Septena xanthostola xantha</i>	N
Hesperiidae	Pyrginae	<i>Spialia dromus</i> (Plötz)	N
Hesperiidae	Pyrginae	<i>Spialia mafa higginsii</i> (Evans)	N
Hesperiidae	Pyrginae	<i>Spialia mangana</i> (Rebel)	N
Hesperiidae	Pyrginae	<i>Spialia ploetzi ploetzi</i> (Aurivillius)	N
Hesperiidae	Pyrginae	<i>Spialia spio</i> (Linnaeus)	OHPS

TABLE 2: Continued.

Family	Subfamily	Species	E-cat
Hesperiidae	Hesperiinae	<i>Tagiades fesus</i>	N
Lycaenidae	Lipteninae	<i>Tetrarhanis diversa ilala</i> (Riley)	N
Nymphalidae	Danainae	<i>Tirumala formosa morgeni</i> (Honrath)	FEW
Nymphalidae	Danainae	<i>Tirumala petiverana</i> (Doubleday & Hewitson)	MS
Lycaenidae	Polyommatainae	<i>Triclema nigeriae</i> (Aurivillius)	FEW
Lycaenidae	Polyommatainae	<i>Tuxentius margaritaceus margaritaceus</i> (Sharpe)	WSS
Lycaenidae	Polyommatainae	<i>Uranothauma falkensteini</i> (Dewitz)	N
Nymphalidae	Nymphalinae	<i>Vanessa cardui cardui</i> (Linnaeus)	N
Nymphalidae	Nymphalinae	<i>Vanesula milca latifasciata</i> (Joicey & Talbot)	FEW
Nymphalidae	Satyrinae	<i>Ypthima albida albida</i> (Butler)	FEW
Nymphalidae	Satyrinae	<i>Ypthima antennata antennata</i> (van Son)	OHPS
Nymphalidae	Satyrinae	<i>Ypthima asterope asterope</i> (Klug)	OHPS
Nymphalidae	Satyrinae	<i>Ypthima granulosa</i> (Butler)	OHPS
Nymphalidae	Satyrinae	<i>Ypthima rhodesiana</i> (Carcasson)	N
Hesperiidae	Hesperiinae	<i>Zezonia zeno</i> (Trimen)	FEW
Lycaenidae	Polyommatainae	<i>Zizeeria knysna</i> (Trimen)	WSS
Lycaenidae	Polyommatainae	<i>Zizina antanossa</i> (Mabille)	WSS
Lycaenidae	Polyommatainae	<i>Zizula hylax</i> (Fabricius)	WSS

Codes for different ecological habitat categories. E-cat: Ecological habitat category. FEW (f/m): “forest edge/woodland species”; FDS (F): “forest-dependent species”; MS (m): “migratory species”; OHPS (O): “open habitat specialist species”; SWSS (S): “swamp/wetland specialist species”; WSS (W): “widespread species” that are frequent fallows/grassland habitat users; N (U): “uncertain ecological category”—species of unknown (un-described) habitat preference.

FIGURE 3: Number of butterfly species obtained using different sampling methods in farmlands of central Uganda during 2006.

small-scale grazing fields, hedgerows, and annual/biannual crop fields in the surrounding of forest reserves. Axis 2 was strongly significantly and positively related to environmental factors such as hedgerows, annual/biannual crop fields in the surrounding of forest reserves. Axis 1 was also negatively influenced by environmental factors such as large scale of tea plantations in vicinity of wetlands/swamps, but positively related to fallows. The fourth axis did not have high loadings but was observed to be frequently correlated (positively) to some other environmental factors: fallows and sugar plantation (Table 6). Environmental factors that were identified in the CCA as determinants for butterflies (Table 5) were also among the environmental factors observed to be significantly ($P < 0.05$, LSD test) associated with high species

richness and abundance of butterflies (Table 6) in the coffee-banana agroforest systems. Across studies sites and sampling rounds, these habitats attracted a high number of butterflies both during the rainy and the dry seasons. Practically, few butterfly species were closely associated with “determinant environmental factors” previously identified in the CCA (Table 4) including swampy habitats, fallows, forest plantations, woodlands, stream-edges, tea plantations, and sugar plantations. For example, *Belenois subeida*, *Bicyclus safitza*, *Melanitis leda*, *Charaxes varanes*, and so forth appeared to be closely associated with fallows (Figure 4). Some of the species closely associated with swamp habitats and forest plantations may be considered as “farmland habitat specialists.” The rest of species may be “generalist farmland habitats users.”

TABLE 3: Butterfly species richness, abundance (individuals/2 ha/site), and diversity (H') in 26 different study sites in the coffee-banana farming system in central Uganda in 2006.

Clusters	Sites	Land use intensity gradients	Species richness	Abundance	Diversity
Bujjagali	Bukose	High	$18.17 \pm 1.56c$	$287.17 \pm 8.38b$	$2.31 \pm 0.28b$
	Namizi-east	High	$23.41 \pm 3.06b$	$510.13 \pm 11.33b$	$2.24 \pm 0.17e$
	Namizi-west	High	$14.61 \pm 0.69c$	$230.23 \pm 8.11b$	$2.67 \pm 0.21d$
	Nawangoma	High	$17.46 \pm 0.71c$	$274.33 \pm 6.09b$	$2.12 \pm 0.11f$
Kalagi	Bamusuta	Medium	$20.54 \pm 0.63c$	$392.36 \pm 8.72b$	$2.95 \pm 0.21c$
	Kifu	Medium	$29.13 \pm 3.39b$	$541.57 \pm 12.03b$	$3.35 \pm 0.33b$
	Kimwanyi	Medium	$31.81 \pm 3.59b$	$562.88 \pm 12.51b$	$3.36 \pm 0.37b$
	Kiweebwa	Medium	$30.23 \pm 1.51b$	$1062.6 \pm 15.93a$	$3.24 \pm 0.25b$
Kamuli	Naikesa	High	$12.45 \pm 0.32d$	$151.87 \pm 3.37c$	$1.81 \pm 0.22g$
	Namulekya	High	$16.62 \pm 0.83c$	$213.34 \pm 7.74b$	$1.87 \pm 0.20g$
Kaweri	Luwunga	Very high	$18.37 \pm 0.51c$	$150.52 \pm 3.34c$	$1.69 \pm 0.21g$
	Nonve	Very high	$11.76 \pm 0.58d$	$141.49 \pm 3.14c$	$1.61 \pm 0.19g$
Lugazi	Kasaku	Very high	$26.22 \pm 2.31b$	$780.68 \pm 16.67a$	$3.22 \pm 0.12b$
	Sugar	Very high	$15.89 \pm 0.79c$	$269.57 \pm 8.99b$	$2.13 \pm 0.32f$
Mabira	Bulyasi	Medium	$22.16 \pm 1.11c$	$409.58 \pm 9.10b$	$3.09 \pm 0.21c$
	Kinoni	Medium	$16.44 \pm 1.82c$	$316.12 \pm 7.02b$	$2.64 \pm 0.31d$
Masaka	Kasaala	Medium	$19.19 \pm 2.12c$	$421.48 \pm 9.37b$	$2.44 \pm 0.16e$
	Katwadde	Medium	$21.22 \pm 2.36c$	$426.59 \pm 9.48b$	$2.63 \pm 0.24a$
	Kiwaala	Medium	$28.87 \pm 3.23b$	$625.57 \pm 19.90a$	$3.35 \pm 0.27b$
	Mpugwe	Medium	$19.24 \pm 2.13c$	$217.69 \pm 7.840b$	$2.51 \pm 0.33d$
Mpigi	Lukalu	Medium	$44.65 \pm 4.95a$	$716.67 \pm 17.86a$	$3.41 \pm 0.25a$
	Mpanga	Medium	$38.19 \pm 4.23a$	$678.57 \pm 17.13a$	$3.56 \pm 0.26a$
Nakaseke	Kimuli	Low	$30.64 \pm 3.41b$	$918.27 \pm 21.71a$	$3.71 \pm 0.27a$
	Kyetume	Low	$20.87 \pm 2.31c$	$368.67 \pm 8.87b$	$3.14 \pm 0.29c$
	Lukumbi	Low	$13.67 \pm 2.51c$	$282.88 \pm 7.44b$	$3.12 \pm 0.23c$
	Segalye	Low	$27.65 \pm 3.06b$	$482.98 \pm 11.67b$	$3.01 \pm 0.23c$

Within columns, means followed by the same letter are not significantly different at 5% probability level (LSD test) test.

3.3. Effects of Farm Management Regimes on Butterflies. Although large monocultures (tea, sugar, coffee plantations) that are intensively managed appeared among important factors in the CCA analysis (Table 4), the species richness, abundance and diversity of butterflies were significantly ($P < 0.05$, LSD test) higher in traditional small-scale polyculture fields than in large monoculture plantations (Table 7). These results indicated that small scale polyculture fields supported richer butterfly communities than did large monoculture (modernized fields).

4. Discussion

4.1. Determinants of Butterfly Species Distribution in Coffee-Banana Farming Systems. In this study, it is predicted that there would be no statistical differences among sites with different land uses, seminatural habitats, and farm management systems for the abundance, richness and diversity of

butterflies since farmland habitats are subjected to constant anthropogenic disturbances. The results did not confirm the hypothesis since there were significant differences in species richness and abundance among the 26 study sites with different land-use types, habitat types and farm management regimes. Sites that hosted higher species richness and diversity were study sites that were riparian forest reserves or sites for which agricultural matrices were surrounded by forest patches and wetlands (see agroforests characteristics in Table 1). In contrast, the least diverse study sites or sites characterized by low butterfly species richness were also study sites of low habitat heterogeneity. These were also sites dominated by high management intensities (sites subjected to high cropping intensity) or sites located in regions with high land-use intensity gradients.

Overall butterfly species richness and density varied seasonally, with more species and higher densities in the rainy seasons (wet months) compared with the dry season (dry months). It is likely that seasonal changes in species

TABLE 4: Summary of canonical correspondence analysis (CCA) ordination results relating butterfly community to environmental variables measured across 26 study sites in 2006.

Axes	Summary				Total inertia
	1	2	3	4	
Eigenvalues	0.267	0.243	0.239	0.208	3.549
Species-environment correlations	0.955	0.950	0.883	0.942	
Cumulative percentage variance					
of species data	7.51	14.34	20.92	26.68	
of species-environment relation	16.32	31.19	45.38	57.72	
Sum of all eigenvalues					3.549
Sum of all canonical eigenvalues					1.639
Summary of Monte Carlo test					
Test of significance of first canonical axis					Eigenvalue = 0.269
					F-ratio = 1.218
					P value = 0.9469
Test of significance of all canonical axes					Trace = 1.638
					F-ratio = 1.289
					P value = 0.0159

TABLE 5: Coefficient of correlations between the matrix of environmental (habitat/land-use) variables and the 4 axes of the CCA ordination scores. Different levels of significance of Spearman rank coefficients of correlation of the environmental variables with axes: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; ns: $P > 0.05$. Correlations indicate the degree to which species occurrence and distributions correspond to changes in each variable in the environmental matrix.

Variable codes	Definition of environmental (habitat/land use) variables that were measured concurrently with butterfly surveys	AX1	AX2	AX3	AX4
Ag fi	Small-scale agroforestry fields with fruit tree species	−0.025 ns	−0.2264 ns	0.6265***	−0.2697 ns
Pla cof	Large coffee plantations in the margins of native forest fragments	0.158 ns	0.0732 ns	0.5488**	0.0641 ns
Fo p	Annual/biannual crop fields in the surrounding of forest reserves	0.1809 ns	0.5947**	0.4686*	0.2083 ns
Gr pl	Small-scale grazing fields (cows, goats, sheep) + hedgerows	0.2799 ns	0.5748**	0.4771*	0.1021 ns
Fall	Fallows (young, old, forest and mixed fallows)	0.521**	−0.1895 ns	−0.0199 ns	0.4696*
SS field	Small-scale monoculture/polyculture fields of annual/biannual crops	0.3531 ns	0.2615 ns	0.631**	−0.0049 ns
Sugar	Large sugar plantations with large water canals	−0.1413 ns	−0.0512*	−0.2619 ns	0.4583*
Sw hbt	Swampy habitats + reclaimed wetlands + stream-edges	0.1242 ns	−0.495*	0.5256**	−0.2101 ns
Tea	Large-scale of tea plantations in vicinity of wetlands/swamps	−0.4515*	−0.001 ns	−0.3991*	0.0468 ns
Wldd	Woodlots (Eucalyptus/Pine plantations) + woodlands + grasslands	0.0325 ns	0.452*	0.5594**	0.2514 ns

richness and density of butterflies may be attributed to monthly variations in climatic factors such as temperature and precipitation. The seasonality in butterfly species occurrence tended not to follow very closely the general patterns of rainfall in central Uganda. However, peak in butterfly species richness appeared to coincide with peaks in flowering of the most butterfly food plants.

In this study, it was observed that sites with higher cover of pasturelands, grasslands, woodlands, fallows, swamps, and stream edges had great diversity, species richness and population density compared to sites with high tree cover in their surroundings. Also, species richness was highest in study sites that were riparian forest fragments and related natural habitats (wetlands). Additionally, it was observed that study sites with higher farm management intensities were less diverse since large monoculture plantations supported less species rich butterfly communities compared to small-scale

fields. The significant difference in mean species richness and diversity across sites was also accounted for by the difference in site characteristics (difference in quality of seminatural and natural habitats found within and in the vicinity of fields). The high species richness of butterflies found may be explained by the fact that mosaic of farm landscapes of central Uganda are characterized by diverse habitat types within the heterogeneously used agricultural matrix that contain a variety of host plants and breeding sites required by butterfly species belonging to different ecological groups. Additionally, strongest differences observed in species richness, abundance, and diversity were apparently related to site biophysical characteristics (see agroforests characteristics in Table 1).

The influence of site biophysical characteristics on diversity and abundance of butterflies was also supported by the ordination analysis. The presence of forest reserves,

TABLE 6: Richness and abundance of butterflies attracted to different habitats (land uses) frequently observed in the coffee-banana farming systems of central Uganda. (Most attractive habitats were those with >20% of weeds/crops/grass/wild plant species blooming or with buds in flowers at the time of visit.)

Foraging habitats: seminatural habitat types/crop-field habitat types	Habitat Frequency	Habitat size range (ha)	N	Butterfly species ($x \pm SE$)	Butterfly abundance ($x \pm SE$)
Field margins associated with or not termite mounds and shrubs/trees/grass species	125	0.05–0.5	159	$5.70 \pm 0.41d$	$16.91 \pm 3.52c$
Boundaries of small-scale polyculture/monoculture fields	96	0.01–0.05	150	$3.70 \pm 0.81e$	$27.42 \pm 3.65c$
Forest reserves in vicinity of small-scale fields and large coffee plantations	25	0.5–40	45	$21.2 \pm 2.12a$	$55.83 \pm 12.1a$
Woodlands, grasslands	15	0.5–40	30	$16.5 \pm 1.07b$	$31.44 \pm 2.87c$
Forest plantations (Pine/Eucalyptus)	11	0.5–30	22	$13.1 \pm 0.34b$	$24.61 \pm 0.21c$
Simple and complex traditional agroforests with fruit trees + pulse crops + cereals + root/tuber crops	34	0.05–2.9	119	$14.56 \pm 1.21b$	$29.34 \pm 2.72c$
Agroforestry woodlots (with species like <i>Moringa</i> sp., <i>Sesbania</i> sp., <i>Leucaena</i> sp., <i>Calliandra</i> sp., etc.)	21	0.05–2	45	$3.12 \pm 0.55e$	$19.55 \pm 5.61c$
Grazing fields, pastures, hedgerows	67	0.05–10	190	$9.90 \pm 1.87c$	$17.86 \pm 4.67c$
Swampy habitats, wetland-edges, streams-edges	54	0.3–5	89	$17.7 \pm 2.51b$	$67.87 \pm 18.2a$
Abandoned gardens	46	0.02–1	258	$10.1 \pm 1.12c$	$41.58 \pm 7.67b$
Fallows (young, old, and forest fallows)	100	0.03–3	356	$16.4 \pm 1.97b$	$46.69 \pm 8.76b$
Herbaceous or unweeded crop fields and unplowed fields	121	0.02–3	367	$16.78 \pm 1.56b$	$36.89 \pm 1.15c$
Perennial crops (e.g., large plantations of coffee/sugar cane)	89	0.05–12	600	$3.92 \pm 0.23e$	$16.32 \pm 1.11c$
Perennial crops (banana) grown sole or mixed with coffee and <i>Vanilla</i>	65	0.05–15	789	$1.18 \pm 0.92h$	$3.268 \pm 0.25d$
Perennial tree fruit crops (avocado, mango, citrus, lemon, guava, papaya, etc.) grown sole	25	0.03–10	98	$3.76 \pm 0.98e$	$16.43 \pm 1.13c$
Perennial fruit crops (passion fruit) grown sole	12	0.01–3	22	$3.12 \pm 1.13e$	$15.65 \pm 1.59c$
Homegardens of annual vegetables (pumpkin, watermelon, cleome, etc.)	48	0.01–0.5	79	$4.62 \pm 0.47d$	$25.78 \pm 1.43c$
Annual commercial/cash vegetable crops (tomato, egg plant, pepper) grown sole or mixed	38	0.02–6	121	$2.11 \pm 0.95f$	$10.21 \pm 2.35d$
Annual commercial/cash crops (sim-sim, sun flower) grown sole or mixed with legumes	15	0.02–10	48	$2.12 \pm 0.88f$	$13.59 \pm 2.45d$
Annual cereals mixed with pulse crops (beans, cowpea, greengram, soybean): Maize	61	0.04–7	421	$2.13 \pm 0.81f$	$5.12 \pm 0.59e$
Annual cereals mixed with pulse crops: sorghum/millet	19	0.03–6	259	$3.17 \pm 0.97e$	$11.67 \pm 2.11d$
Annual cereals (maize, sorghum, millet) mixed with pulse crops (beans, groundnut): Beans	41	0.02–5	342	$2.43 \pm 0.31f$	$9.625 \pm 2.61d$
Annual cereals mixed with pulse crops: Groundnut, cowpeas	26	0.02–6	403	$1.23 \pm 0.34h$	$4.624 \pm 0.54e$
Bi-annual crops (cassava)	26	0.02–8	198	$1.12 \pm 0.16h$	$4.232 \pm 0.98e$
Annual crops (sweet potato)	51	0.02–3	400	$4.32 \pm 0.67d$	$8.963 \pm 2.42d$
Annual cereals (rice)	16	0.05–15	55	$1.13 \pm 0.13h$	$4.651 \pm 0.87e$
Annual crops (Irish potato)	28	0.05–12	43	$2.45 \pm 0.41h$	$12.34 \pm 2.76d$

Habitat frequency: number of observation cases or number of times the habitat type was encountered across all 26 study sites and all sampling rounds.

Habitat size range (ha): the data show the minimum and the maximum size of the type of habitat encountered during butterfly faunistic surveys.

N: number of samples (butterfly species and individuals) recorded in five sampling rounds across the 26 study sites in 2006.

Within columns, different letters show significant differences of the means at $P = 0.05$ according to LSD test performed after Kruskal Wallis-ANOVA test indicated that the habitat type was significant ($P < 0.001$) for the number of species and individuals attracted.

TABLE 7: Effect of the farm intensity management system on the richness, abundance, and diversity of butterfly found in the coffee-banana farming system in central Uganda.

Farm management systems	Species richness (number species/site)	Abundance (individuals/site)	Diversity (Shannon-diversity index: H')
Modernized (large-scale fields)	14.21 $\pm$ 2.73b	330.2 $\pm$ 79.55b	2.28 $\pm$ 0.81b
Traditional (small-scale fields)	19.95 $\pm$ 4.41a	685.7 $\pm$ 231.47a	2.89 $\pm$ 1.59a

Within each column, means followed by the same letters are not significantly different at 5%, LSD test.

FIGURE 4: Canonical correspondence analysis (CCA) ordination diagram biplot showing correlation between butterfly specie (*Acra joh*, *Mela led*, and *Bicy sau* are short names of specie) and the environmental variables (codes: solid line vector “Tea,” “Sw hbt,” “Fall,” etc.).

woodlands, fallows, hedgerows, woodlots (pine/eucalyptus forest plantations) in the vicinity of fields were environmental factors that appeared to be more important and primary determining the occurrence of foraging butterfly species composition. The ordination analysis demonstrated that the occurrence of different butterfly species in the farmland was strongly positively association with availability of natural and seminatural habitats found in the surrounding of fields. Thus, seminatural and natural habitats are among environmental factors playing key roles in shaping butterfly communities potentially delivering pollination services to wild and cultivated plants in the coffee-banana agroforestry systems of central Uganda.

4.2. Butterfly Assemblages in Tropical Agroforestry Systems. In this study, farmlands were hypothesized not to be suitable habitats for diverse butterfly communities in central Uganda. In contrast to expectations, the results indicated that farmlands of central Uganda supported a rich butterfly fauna and that there were significant ($P < 0.05$) variation in species richness, abundance and diversity among the 26 sites studied. Small-scale polyculture fields and other traditional complex

agroforestry systems that were established in the vicinity of forests fragments or traditional simple agroforestry systems with a high cover of seminatural habitats (fallow, swamps, hedgerows) supported more species and individuals of butterflies than other typical cropping systems. These important agroforestry systems supported also a high number of species of butterfly food plants. Several butterfly food plants species were recorded in a previous study [7].

In this study it was observed that farmlands of central Uganda supported species rich-butterfly faunas that are highly seasonal. The high number of butterfly species and individuals recorded in small scale polycultures indicated that a certain number of wild and cultivated plant species were receiving Lepidoptera pollination services of high quality. In other words, several butterfly species occurring in the farmland of central Uganda may be efficient pollinator species on many cultivated and wild plant species (subspecies, land races, genotypes, varieties). In fact, some butterfly species in the Lycaenidae, Nymphalidae family were frequently recorded collecting floral resources on several weeds/crops in bloom that were found in different small scale field where cereals and legumes were mixed. In farmlands of central Uganda, butterflies have been observed being engaged in different activities (perching, flying, mating, foraging, and oviposition). With field experience, some butterfly species were observed making long visits on crop flowers such as cowpeas, beans, groundnut, and egg plants. They made their visits to crop flowers mainly between 9 h00 and 11 h00 and between 14 h00 and 16 h00 (Figure 5).

In central Uganda, *Catopsilia florella*, *Bicyclus safitza*, *Junonia Sophia*, and *Acraea acerata* were especially abundant while a much larger number of species were relatively rare (>60% of species recorded), reflecting patterns expected from tropical environments. These species appeared to be well adapted for survival in farmlands of central Uganda. They are well known to be abundant in grassland habitats in Uganda [7]. They are probably typical farmland species as no reports have ever mentioned them among the dominant species of forest ecosystems in Uganda. In addition, *Catopsilia florella* and *Acraea acerata* have been reported by local farmers to be pests, although scientific evidence indicates that only *A. acerata* is a pest of crop species such as sweetpotato [30]. Similar observations were reported by Fernández-Hernández [31] in Cuba.

Farmland butterflies are believed to pollinate many wild and cultivated plant species. Pollination activities of some species are well known. Continuous observations are needed in the future in order to determine the pollination efficiency

FIGURE 5: Distribution of the daily activities of few butterfly species that were monitored when visiting crop field habitats in central Uganda in 2006—preliminary results. With author experience, observations were recorded ($N = 679$ observations conducted on 5 butterfly species).

of all butterfly species on wild and cultivated plant species. This may help in development of strategies for their conservation and management within farmland habitats. The functional status (as pest or as pollinator) of *Catopsilia florella* remains largely unknown. This species disperses locally and in this study, the species was observed foraging frequently on both flowering herbs/weeds and on some crop species.

In central Uganda, farmlands were found to be visited by a high number of species of “forest dependent species” (mainly Nymphalidae). This finding contrasts with observations of Fermon et al. [32] who found that the majority of Nymphalidae species were avoiding farmlands located in the vicinity of forest habitats. Fermon et al. [32] stressed that only a few specialist nymphalid species could visit pine/eucalyptus plantations adjacent to the natural forests in Bossematie zone (Cote D’Ivoire). The main reason for central Uganda to support high butterfly diversity dominated by Nymphalidae is the presence of forest patches within agricultural matrices, making central Uganda to appear more like “small degraded forests than just typical agricultural mosaic landscape” [7].

4.3. Patterns of Butterfly Diversity and Abundance in Farmland Habitats. In this study, a great variation in species richness and density among the 26 study sites was observed. The most species-rich site contained more than four times the number of species as the poorest site overall. The highest species richness, population density, and diversity of butterflies were found to be associated with study sites that are riparian forest reserves (see Table 1).

Much as factors governing butterfly community structure and composition in farmlands are not fully known, this

result indicates that forest vegetation play a significant role in the distribution, diversity, and density of butterfly species in farmlands of central Uganda. A possible explanation is that butterflies visit farmlands for supplemental nectar resources not found in the adjacent forest ecosystems.

In East Africa, farmlands are expected to be populated by a small number of butterfly species, generally 5 to 50 represented by a relatively high number of individuals. While in this study it was observed that a high number of forest-dependent species (40% of 331 species recorded), including fruit-feeding species, that visited crop fields located in the adjacent; a recent study conducted in Ghana found that very few (<10% of 90 species recorded) fruit-feeding species occurred in the farm bush savannah [33].

Several studies indicate that farmland habitats support poor communities of butterflies [14, 34–36]. However, few studies have highlighted similar findings to those obtained in central Uganda. For example, in Vietnam, Lien and Yuan [37] recorded a higher diversity of butterflies in agricultural habitats [28, 37]. Similar observations were recorded by Lien and Yuan [37] in Costa Rica where high species richness of butterfly was recorded in coffee plantations as compared to adjacent forest remnant fields. In addition, Kitahara [21] recorded higher species richness and diversity in agricultural landscapes in Japan compared to forest fragments. These previous studies show that elsewhere (out of sub-Saharan Africa) farmland habitats can be important for butterflies comparable to forest ecosystems as it was observed in central found in Uganda.

In conclusion, the overall objective of this study was to provide information on butterfly communities to conservation planners and policy makers in central Uganda. The results show that the species diversity of butterfly in the coffee-banana agroforestry systems of central Uganda is much higher than expected. Butterflies visited a variety of habitats and land uses, some of them were better than others to harbor butterflies. Important habitats for farmland butterflies included woodlands, fallows, hedgerows, swampy habitats, abandoned gardens, and homegardens.

Findings from this study indicated that agricultural field sites that were riparian forest fragments/wetlands had the highest species richness and population density of butterflies compared to field sites established far from natural habitats (forests, wetlands). They might support the concept of corridors across large agricultural areas.

Higher forest cover within landscapes had a major positive influence on butterfly biodiversity in agricultural landscapes and related human-modified landscapes in central Uganda.

Although data was collected during five rounds (knowing that five samples may not be enough for robust statistical analysis) conducted in only one year (2006), this study supplied valuable information about the diversity of butterflies in coffee-banana agroforestry areas in central Uganda. The research findings indicated that local coffee-banana agroforestry systems are valuable for butterfly conservation.

A high number of species and individuals were recorded in small scale polycultures. This indicated that some wild and cultivated plant species were potentially receiving pollination

services of high quality from different butterfly species. There is a need to develop appropriate strategies to conserve coffee-banana agroforests to maintain butterfly communities delivering pollination services to crops and wild plants within and nearby crops habitats. The conservation of remnant forest patches through restoration of different habitats, protection from degradation and improvement of the connectivity to larger forest patches and related man-made forest plantations (woodlots, forest plantations) needs to be prioritized by policy makers and land-use planners. Their protection from degradation should be a priority for decision makers since these forest support a rich community of butterflies potentially delivering pollination services to cultivated plants on which human beings depend on for their livelihoods.

Farmers are advised to adopt landscape management and farming practices that are friendly to butterfly species pollinating some of their crops such as practices that can increase high on-farm cover (%) of different types of land uses (polycultures of cereals mixed to legume crops, traditional simple and complex agroforestry systems), of seminatural features (hedgerows, fallows, grasslands, pasturelands, swampy habitats, stream-edges) and related habitats (forest patches, forest fallows, woodlots of eucalyptus, pines) or farming practices that protect and increase the area covered by noncrop habitats within farmed landscape to serve as “butterfly reservoirs.” Such uncultivated areas can also support larval host plants and various nectarine plant species that may attract different adult butterfly species in the farmlands.

Farmers are recommended to invest in the protection of habitats to offer habitat and nectar sources to butterflies in the farmland. The protection of natural and seminatural habitats in the coffee-banana farming system may be of different uses: serving as source of butterflies for a butterfly farm. The coffee-banana farming system may also be used as tourist place to see common farmland butterflies species. More practically, they need protection since preliminary observations indicated that some cultivated crops were receiving pollination services [7] from some butterfly species.

Farm management regime had an impact of butterfly diversity such as small scale farms supported highly diverse butterfly communities than did modernize large plantations. Therefore, farmers are encouraged to adopt polyculture cropping systems integrated to good management of floral resources in the margins of fields.

To provide contributions to the conservation of butterfly fauna in agricultural landscapes in Uganda, it is important to determine the pollination efficiency of different butterfly species. The recommended correct sampling method to bring appropriate result is transect count. This method may be a suitable method to assess the diversity of butterfly communities delivering pollination services to wild and cultivated crops in different farmland habitats of central Uganda. The method is recommended to be used for monitoring butterflies, as well as assessing impact of habitat disturbance on community diversity of butterflies. Banana-bait trap method may be recommended for assessing/monitoring fruit feeding community in the area while hand net may be used

when aiming at detecting rapidly a high number of species in the habitat.

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